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(21)Application number :	2001-004485	(71)Applicant :	MITSUBISHI HEAVY IND LTD
(22)Date of filing :	12.01.2001	(72)Inventor :	MIZUI JUNICHI MIKI SUSUMU AKAHA TAKASHI

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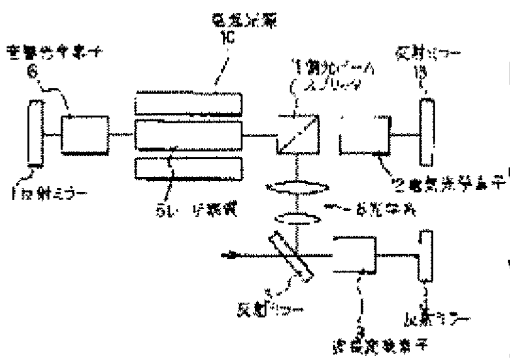
(54) LASER DEVICE WITH WAVELENGTH CONVERSION ELEMENT

(57)Abstract:



PROBLEM TO BE SOLVED: To provide a laser device having a wavelength conversion element which improves the wavelength conversion efficiency.

SOLUTION: An acousto-optical element 6 generates a pulse laser beam by the Q-switch oscillation as a fundamental wave laser beam which is then confined between reflection mirrors 1, 13 to amplify to a sufficient intensity, while a voltage is applied to an optoelectronic element 12 to turn a polarized plane of the fundamental wave laser beam 90° to make it incident on a polarized beam splitter 11. The splitter 11 passes the fundamental wave laser beam with its optical axis deflected 90° to make this beam incident on a wavelength conversion element 9 via a reflection mirror 3, and a wavelength-converted laser beam converted by this conversion element 9 is taken out via the reflection mirror 3.

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[Claim(s)]

[Claim 1] The laser equipment which has the wavelength sensing element characterized by to constitute so that a resonator optical axis changes and the above-mentioned wavelength sensing element may enter in a resonator optical axis by operating an

optical-axis modification means when a wavelength sensing element does not put in in the resonance optical axis of the resonator concerned but the above-mentioned reinforcement becomes sufficiently large until the reinforcement of the fundamental-wave laser beam which is the pulse laser light in the resonator which a laser medium generates becomes sufficiently large in the laser equipment which has a wavelength sensing element in a resonator .

[Claim 2] It is laser equipment which has the wavelength sensing element characterized by obtaining by carrying out the Q switch oscillation of the laser beam in which a laser medium generates pulse laser light in the laser equipment which has the wavelength sensing element indicated to [claim 1].

[Claim 3] The laser medium which is excited by the excitation light source and oscillates a fundamental-wave laser beam in the laser equipment which has a wavelength sensing element in a resonator, The reflective mirror pair which forms the resonator to which is arranged in the both sides of this laser medium, reflects the above-mentioned fundamental-wave laser beam, and a laser medium is made to go and come back, A plane-of-polarization rotation means to rotate the plane of polarization of the light to which it goes and comes back between this reflective mirror pair, A beam splitter mirror with wavelength selection nature which it is installed [nature] on the polarizer which makes the direction of an optical axis of a laser beam which plane of polarization rotated change, and the laser beam shaft with which the direction was changed, and a fundamental wave is reflected [nature], and makes wavelength conversion light penetrate, The wavelength sensing element installed on the optical axis so that the fundamental-wave laser beam which has furthermore passed along the changed optical axis could pass, Laser equipment which has a wavelength sensing element in the resonator which consists of a reflective mirror which forms in up to the original optical axis again the resonator installed by return [light] in two waves, a fundamental wave and wavelength conversion light, in order so that a laser beam might be returned after passing a wavelength sensing element.

[Claim 4] Laser equipment which has the wavelength sensing element characterized by establishing a Q switch oscillation means to carry out the Q switch oscillation of the laser beam which a laser medium generates in the laser equipment which has the wavelength sensing element indicated to [claim 3], and to obtain the fundamental-wave laser beam which is pulse laser light.

[Claim 5] It is laser equipment which has the wavelength sensing element characterized by constituting from an electro-optics component for which a plane-of-polarization rotation means rotates the plane of polarization of a

fundamental-wave laser beam by impression of an electrical potential difference in the laser equipment indicated to [claim 3].

[Claim 6] It is laser equipment which has the wavelength sensing element characterized by constituting a polarizer from a polarization beam splitter in the laser equipment indicated to [claim 3].

[Claim 7] [claim 1] -- or the laser equipment which has the wavelength sensing element characterized by forming a laser medium by solid-states, such as a YAG crystal, in the laser equipment which has any one wavelength sensing element indicated to [claim 6].

[Claim 8] [claim 1] -- or the laser equipment which has the wavelength sensing element characterized by forming a wavelength sensing element as 2 double harmonic generation crystals, such as KTP (KTiOPO4) and BBO (BaB 2O4), in the laser equipment which has any one wavelength sensing element indicated to [claim 6].

[Claim 9] [Claim 1] Or laser equipment which has the wavelength sensing element characterized by inserting contraction optical system, such as a lens system and a mirror system, and condensing just before light carries out incidence of the fundamental-wave light of solid state laser to a wavelength sensing element in the laser equipment which has which one wavelength sensing element indicated to [claim 8], in order to aim at improvement in conversion efficiency in a wavelength sensing element.

[Claim 10] [Claim 1] Or laser equipment which puts the wavelength sensing element for harmonic generations into coincidence 3 times as a wavelength sensing element in the laser equipment which has which one wavelength sensing element indicated to [claim 8] with the wavelength sensing element for two-times harmonic generations of the wavelength sensing element of [claim 8], and has as an output two-times higher-harmonic light, 3 time higher-harmonic light, or the wavelength sensing element characterized by enabling it to take out only higher-harmonic light 3 times.

[Claim 11] [Claim 1] Or laser equipment which has the wavelength sensing element characterized by to make it like using contraction optical system, such as a lens system and a mirror system, after the wavelength sensing element for two-times harmonic generations, condensing to coincidence, putting fundamental-wave light, two-times higher-harmonic light, or both into the wavelength sensing element for harmonic generations 3 times in the laser equipment which has the wavelength sensing element indicated to [claim 8], or [claim 10], and aiming at improvement in conversion efficiency of a harmonic generation 3 times.

[Claim 12] [Claim 1] Or laser equipment which has the wavelength sensing element to which oscillation core wavelength is characterized by putting in beforehand almost same another narrow-band continuous-wave-laser light, and performing pulse

oscillation actuation of a fundamental wave by injection locking in the laser equipment which has which one wavelength sensing element indicated to [claim 11] in order to narrow-band-ize oscillation wavelength width of face of fundamental-wave light.
[Claim 13] [Claim 1] Or laser equipment which has the wavelength sensing element characterized by making the polarization direction in laser go as S polarization so that loss of the light which goes and comes back to the inside of a resonator can be smallest performed in the laser equipment which has which one wavelength sensing element indicated to [claim 12], and making laser beam loss with a polarizer small.
[Claim 14] [claim 1] -- or the laser equipment which has the wavelength sensing element characterized by to use the concave surface mirror with curvature designed so that the diffraction loss of the light in a resonator might be made small, while each resonator mirror uses the mirror of a high reflection factor so that loss of the light which goes and comes back to the inside of a resonator may be smallest performed in the laser equipment which has which one wavelength sensing element indicated to [claim 13].

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention is useful as pulse laser oscillation equipment especially applied to surface treatment, such as ingredient processing of perforation, cutting, welding, etc. and exposure, surface treatment, and marking, about the laser equipment which has a wavelength sensing element.
[0002]
[Description of the Prior Art] There is some laser equipment which oscillates the pulse laser light for applying to surface treatment, such as ingredient processing of perforation, cutting, welding, etc. and exposure, surface treatment, and marking, and which has a wavelength sensing element in the resonator. This kind concerning the conventional technique of laser equipment is shown in drawing 8 . As shown in this drawing, this laser equipment constitutes a resonator from reflective mirrors 1, 2, 3, and 4, and the optical system 8 and the wavelength sensing element 9 for extracting the laser medium 5 of an YAG laser, the acoustooptics component 6 for Q switch actuation, and a laser beam cross section are arranged in this resonator.
[0003] Here, the laser medium 5 is excited with the excitation light which the excitation light source 10 generates, and generates a laser beam. This laser beam is called a fundamental-wave laser beam. Moreover, the wavelength sensing element 9 carries out wavelength conversion of the laser beam which carried out incidence at 2 double higher harmonic. Thus, the laser beam which carried out wavelength conversion is called a

wavelength conversion laser beam. The reflective mirrors 1 and 2 are arranged at the both sides of the laser medium 5 and the acoustooptics component 6 so that the fundamental-wave laser beam which the laser medium 5 generates may be reflected. Moreover, optical system 8 is arranged between the reflective mirror 2 and 3, and the wavelength sensing element 9 is arranged between the reflective mirror 3 and 4. While the reflective mirror 3 reflects a fundamental-wave laser beam, it penetrates the wavelength conversion laser beam which carried out wavelength conversion by the wavelength sensing element 9. A wavelength conversion laser beam also reflects the reflective mirror 4 with a fundamental-wave laser beam.

[0004] When obtaining pulse laser light with this laser equipment, the laser medium 5 is first changed into the condition that it excites by the excitation light of the excitation light source 10, and light can be emitted spontaneously. The acoustooptics component 6 is operated in this condition, and it considers as the condition which can penetrate a laser beam. That is, Q switch actuation is made to perform. Consequently, while it is reflected by the reflective mirrors 1, 2, 3, and 4 and the laser beam which carried out outgoing radiation from the laser medium 5 goes and comes back to the inside of a resonator, it is amplified whenever it passes the laser medium 5. This actuation is the pulse oscillation of a fundamental-wave laser beam. If a laser beam passes the wavelength sensing element 9 at this time, since wavelength conversion of a part of fundamental-wave laser beam will be carried out, it will become 2 double higher harmonic and the reflective mirror 3 will penetrate this wavelength conversion laser beam, only this wavelength conversion laser beam can be taken out outside as an output of the laser equipment concerned.

[0005]

[Problem(s) to be Solved by the Invention] It is, if the pulse forming which enlarges oscillation laser reinforcement in time where the wavelength sensing element 9 which causes loss at the time of a pulse oscillation is included in the laser equipment like **** is not carried out and it is ****, and it is **. For this reason, the pulse concerned has a late standup, maximum will be small and pulse width will become a long pulse. For this reason, the count to which a laser beam goes back and forth between resonator mirrors increases, and loss by absorption of the optical mirror between resonators or a wavelength sensing element, the diffraction loss in dispersion and a resonance mirror, etc. becomes remarkable. Moreover, since the maximum reinforcement of a pulse was small, the output of the wavelength conversion light which the wavelength conversion efficiency proportional to the field strength of light becomes small, and is obtained as a result was small, and pulse width was [the ********] a problem further. The long wave

length conversion light of pulse width has small field strength like the above, when changing short wavelength further using the wavelength conversion light, and the technical problem to which conversion efficiency falls produces it.

[0006] the laser equipment with which this invention has a wavelength sensing element in view of the above-mentioned conventional technique -- it is and aims at offering the laser equipment which can raise wavelength conversion efficiency.

[0007]

[Means for Solving the Problem] The configuration of this invention which attains the purpose like **** is as follows.

[0008] 1) It constituted so that a resonator optical axis changes and the above-mentioned wavelength sensing element may enter in a resonator optical axis by operating an optical-axis modification means when a wavelength sensing element is not put in in the resonance optical axis of the resonator concerned but the above-mentioned reinforcement becomes sufficiently large until the reinforcement of the fundamental-wave laser beam which is the pulse laser light in the resonator which a laser medium generates becomes sufficiently large in the laser equipment which has a wavelength sensing element in a resonator.

[0009] 2) Obtain pulse laser light in the laser equipment which has the wavelength sensing element indicated to the above 1 by carrying out the Q switch oscillation of the laser beam which a laser medium generates.

[0010] 3) The laser medium which is excited by the excitation light source and oscillates a fundamental-wave laser beam in the laser equipment which has a wavelength sensing element in a resonator, The reflective mirror pair which forms the resonator to which is arranged in the both sides of this laser medium, reflects the above-mentioned fundamental-wave laser beam, and a laser medium is made to go and come back, A plane-of-polarization rotation means to rotate the plane of polarization of the light to which it goes and comes back between this reflective mirror pair, A beam splitter mirror with wavelength selection nature which it is installed [nature] on the polarizer which makes the direction of an optical axis of a laser beam which plane of polarization rotated change, and the laser beam shaft with which the direction was changed, and a fundamental wave is reflected [nature], and makes wavelength conversion light penetrate, The wavelength sensing element installed on the optical axis so that the fundamental-wave laser beam which has furthermore passed along the changed optical axis could pass, Have a wavelength sensing element in the resonator which consists of a reflective mirror which forms in up to the original optical axis again the resonator installed by return [so that a laser beam may be returned / light] in two waves, a

fundamental wave and wavelength conversion light, in order after passing a wavelength sensing element.

[0011] 4) A Q switch oscillation means to have carried out the Q switch oscillation of the laser beam which a laser medium generates in the laser equipment which has the wavelength sensing element indicated to the above 3, and to obtain the fundamental-wave laser beam which is pulse laser light was established.

[0012] 5) It is having constituted from an electro-optics component for which a plane-of-polarization rotation means' rotates the plane of polarization of a fundamental-wave laser beam by impression of an electrical potential difference in the laser equipment indicated to the above 3.

[0013] 6) It is having constituted the polarizer from a polarization beam splitter in the laser equipment indicated to the above 3.

[0014] 7) It is having formed the laser medium by solid-states, such as a YAG crystal, in the laser equipment which has any one wavelength sensing element indicated to the above 1 thru/or 6.

[0015] 8) It is having formed the wavelength sensing element in the laser equipment which has any one wavelength sensing element indicated to the above 1 thru/or 6 as 2 double harmonic generation crystals, such as KTP (KTiOPO4) and BBO (BaB 2O4).

[0016] 9) In the laser equipment which has which one wavelength sensing element indicated to the above 1 thru/or 8, in order to aim at improvement in conversion efficiency in a wavelength sensing element, just before light carries out incidence of the fundamental-wave light of solid state laser to a wavelength sensing element, insert contraction optical system, such as a lens system and a mirror system, and condense.

[0017] 10) The wavelength sensing element for harmonic generations is put into coincidence 3 times as a wavelength sensing element with the wavelength sensing element for two-times harmonic generations of the wavelength sensing element of the above 8, and it enabled it to take out only two-times higher-harmonic light, 3 time higher-harmonic light, or 3 time higher-harmonic light as an output in the laser equipment which has which one wavelength sensing element indicated to the above 1 thru/or 8.

[0018] 11) It was made like using contraction optical system, such as a lens system and a mirror system, after the wavelength sensing element for two-times harmonic generations, condensing to coincidence, putting fundamental-wave light, two-times higher-harmonic light, or both into the wavelength sensing element for harmonic generations 3 times in the laser equipment which has the wavelength sensing element indicated to the above 1 thru/or 8, or 10, and aiming at improvement in conversion

efficiency of a harmonic generation 3 times.

[0019] 12) In the laser equipment which has which one wavelength sensing element indicated to the above 1 thru/or 11, in order to narrow-band-ize oscillation wavelength width of face of fundamental-wave light, another narrow-band continuous-wave-laser light with the almost same oscillation core wavelength is put in beforehand, and perform pulse oscillation actuation of a fundamental wave by injection locking.

[0020] 13) In the laser equipment which has which one wavelength sensing element indicated to the above 1 thru/or 12, let the polarization direction in laser go as S polarization so that loss of the light which goes and comes back to the inside of a resonator can be performed smallest, and make laser beam loss with a polarizer small.

[0021] 14) In the laser equipment which has which one wavelength sensing element indicated to the above 1 thru/or 13, to be able to perform smallest loss of the light which goes and comes back to the inside of a resonator, each resonator mirror should use the concave surface mirror with curvature designed so that the diffraction loss of the light in a resonator might be made small while using the mirror of a high reflection factor.

[0022]

[Embodiment of the Invention] Hereafter, the gestalt of operation of this invention is explained to a detail based on a drawing. In addition, the same number is given to the same part as the conventional technique shown in the same part and drawing 8 in a gestalt of each operation, and the overlapping explanation is omitted.

[0023] <Gestalt of the 1st operation> drawing 1 is the block diagram showing the gestalt of operation of this invention. As shown in this drawing, the laser equipment concerning this gestalt arranges a polarization beam splitter 11 instead of the reflective mirror 2 in the equipment shown in drawing 8 , and adds the reflective mirror 13 which reflects the electro-optics component 12 and a fundamental wave further. 90 degrees of laser beams of a polarization component perpendicular to this space are bent in the perpendicular lower part in drawing, and a polarization beam splitter 11 makes it penetrate them towards the reflective mirror 3 here while making the laser beam of a polarization component level in the space of drawing 1 among the laser beams by which outgoing radiation is carried out from the laser medium 5 penetrate as it is. That is, incidence of the polarization component which penetrated the polarization beam splitter 11 linearly is carried out to the electro-optics component 12, it penetrates this electro-optics component 12, and is reflected by the reflective mirror 13.

[0024] If the electro-optics component 12 impresses an electrical potential difference at this time, 45 degrees of plane of polarization of a laser beam will be rotated. Thus, the laser beam which it rotates with the electro-optics component 12, it is reflected by the

reflective mirror 13, and carries out incidence to the electro-optics component 12 again rotates 45 degrees of the plane of polarization again. Consequently, by the polarization beam splitter 11, the laser beam which penetrated the polarization beam splitter 11, was reflected by the reflective mirror 13, and went and came back to the electro-optics component 12 turns that optical axis to the reflective mirror 3, and is bent by the perpendicular lower part. On the other hand, the electro-optics component 12 which does not impress an electrical potential difference only passes a laser beam. That is, it is reflected by the reflective mirrors 1 and 13, without that plane of polarization rotating, and the laser beam which passes the electro-optics component 12 at this time goes back and forth between both the reflective mirror 1 and 13. Therefore, it can be made sufficient reinforcement by making between the resonators formed by the reflective mirrors 1 and 13 go, and amplifying in the condition of not impressing an electrical potential difference for the pulse laser light obtained by the Q switch oscillation of the acoustooptics component 6 at the electro-optics component 12.

[0025] Drawing 2 is the wave form chart showing the timing of each part of the laser equipment shown in drawing 1 of operation. The laser medium 5 is first changed into the condition that it excites by the excitation light of the excitation light source 10, and light can be emitted spontaneously, the acoustooptics component 6 is operated in this condition, and a Q switch oscillation is made to perform, as shown in this drawing. The voltage waveform impressed to the acoustooptics component 6 at this time is shown in drawing 2 (a).

[0026] At this time, the electrical potential difference is not impressed to the electro-optics component 12. Therefore, the pulse laser light generated by the Q switch oscillation of the acoustooptics component 6 passing the laser medium 5, it is shut up between the resonators formed by the reflective mirrors 1 and 13, and is amplified by sufficient reinforcement. The wave of the fundamental-wave laser beam which is the pulse laser light at this time is shown in drawing 2 (b).

[0027] When the reinforcement of the fundamental-wave laser beam obtained to the Q switch oscillation of the acoustooptics component 6 becomes max, an electrical potential difference is impressed to the electro-optics component 12. The voltage waveform impressed to the electro-optics component 12 at this time is shown in drawing 2 (c). It is reflected by the reflective mirror 13 by the impression of an electrical potential difference to the electro-optics component 12, and, as for the fundamental-wave laser beam which passes twice, the plane of polarization rotates 90 degrees of electro-optics components 12. And the fundamental-wave laser beam which rotated in this way bends 90 degrees of opticals axis by the polarization beam splitter 11, and is penetrated

towards the reflective mirror 3. Like the laser equipment concerning the conventional technique shown in drawing 8 , when a fundamental-wave laser beam passes the wavelength sensing element 9, wavelength conversion is carried out at 2 double higher harmonic, and the rest penetrates the reflective mirror 3 as a wavelength conversion laser beam of a short pulse, and is outputted outside. The wave of the wavelength conversion laser beam at this time is shown in drawing 2 (d).

[0028] The description of the equipment concerning the gestalt of this operation is because the wavelength sensing element 9 which works as a loss medium of a laser beam does not enter between this resonator until a fundamental-wave laser beam pulse rises enough, as light goes between the resonators which consist of reflective mirrors 1 and 13 and it is shown in drawing 2 (b). For this reason, as for the pulse shape of a fundamental wave, maximum also becomes [a standup] large early rather than an equipment configuration conventionally. Therefore, when it shifts to the configuration which a resonator becomes from the reflective mirrors 1, 13, 3, and 4 and the wavelength sensing element 9 is included in the both-way way of light by switching of the electro-optics component 12 after that, wavelength conversion efficiency improves, and since a fundamental wave is a short pulse, wavelength conversion is completed for a short time. Therefore, since it can decrease in the count itself to which light goes back and forth between resonators since all the processes included to wavelength conversion as a whole for a short time are completed, and the loss of light itself can be small suppressed as the result, wavelength conversion efficiency improves.

[0029] Average output P2w and pulse width deltatp of the two-times wave laser light in laser equipment which have a wavelength sensing element concerning the conventional technique shown in the equipment concerning this gestalt, and drawing 8 The comparison of the numerical-analysis result of an oscillation pulse-repetition-frequency F dependency is shown in drawing 3 . The relation between pulse energy E2w of a two-times wave and average output P2w is P2w=F-E2w. Analysis is Kechner. Work: Solid-State Laser Engineering It was allied and the deformation type of the following which added the term of two-times wave conversion to the existing basic type, and the formula about Gain g were solved.

[0030]

[Equation 1]

$$\frac{dI}{dt} = C\frac{L}{L_O} \cdot g \cdot I - \left(\frac{\varepsilon}{T_R} + \eta_{2\omega}\right) \cdot I$$

For optical reinforcement [W/cm2] and t, time amount [s] and C are [I] the velocity of

light [cm/s], and L and Lo here. For laser medium length [cm], cavity length [cm], and g, gain [l/cm] and epsilon are optical losses other than the wavelength conversion in a resonator, and TR. The time amount [s] to which light is once restored in a resonator, and eta2w are proportional to I with wavelength conversion efficiency. At the first example of this invention, it is an electro-optics component. It was referred to as eta2w=0 until the electrical potential difference was impressed to 12. Lo TR Electro-optics component It was made to change, before and after impressing an electrical potential difference to 12. As this result was shown in drawing 3 , average power P2w is about 50% of increment with a new model (the first example) compared with a conventional type, and pulse width was shortened greatly. Although it is fixed in about 10ns and is 20ns near 1kHz in a conventional type with a new model, it increases to 70ns in 10kHz. Therefore, peak intensity Pmax2w =P2w/(F-delta tp) has improved from 3 times near 1kHz to about 10 times near 10kHz.

[0031] The gestalt of operation of the 2nd of this invention is shown in <gestalt of the 2nd operation> drawing 4 . This gestalt incorporates two wavelength sensing elements in the gestalt of the 1st operation. The configuration whose 15 14 uses a second harmonic generation component and uses a third harmonic generating component as a function of a wavelength sensing element is the most effective combination. Moreover, the reflective mirror 16 reflects a fundamental wave and uses the mirror of a specification which is penetrated to two wavelength after wavelength conversion.

[0032] In the gestalt of this operation, a fundamental wave is shut up between resonators and outputted outside. Therefore, when carrying out wavelength conversion to the 3rd higher harmonic in the photomixing of the 2nd higher-harmonic light and a fundamental wave, the 3rd higher-harmonic component cannot be put on the exterior of a resonator. Therefore, it is effective to incorporate the 3rd higher-harmonic sensing element with the 2nd higher-harmonic sensing element into a resonator like this gestalt. Moreover, since the peak intensity of 2 double wave is increasing remarkably compared with a conventional type as said drawing 3 explained, since the conversion efficiency of a 3 time wave is proportional to the peak intensity of a fundamental wave and a two-times wave, it can expect an increment more remarkable than the case where a wave as well as a conventional type installs two kinds of wavelength sensing elements in a resonator 3 times. In this example, after a two-times wave is changed twice both ways, it is changed into a wave from each two-times wave 3 times.

[0033] As a cure when the angle of divergence of two light of the 2nd higher harmonic increases to a fundamental-wave list in the 2nd wavelength sensing element which mixes a fundamental wave and the 2nd higher harmonic with the gestalt of the 2nd

operation, the gestalt of <gestalt of the 3rd operation> book operation is the configuration of having added the contraction optical system 18 after the second harmonic generation component, as shown in drawing 5 . Peak light reinforcement is spatially enlarged by this contraction optical system 18, and the conversion efficiency of a wave is increased by 3 times. In this example, if the contraction optical system 18 is reversed, since reinforcement falls, it needs to use it from the two-times wave sensing element 14 to the wave sensing element 15 3 times in an one direction.

[0034] ****** concerning the gestalt of the operation of the 4th of this invention to <gestalt of the 4th operation> drawing 6 is shown. The equipment concerned added narrow-band CW laser 19, the reflective mirror 20, the polarization beam splitter 21, the electro-optics component 22, and the quarter-wave length plate 23 to the equipment concerning the gestalt of the 1st operation.

[0035] In this gestalt of this, the light of narrow-band CW laser 19 selects plane of polarization so that it may be reflected in the direction of the quarter-wave length plate 23 by the polarization beam splitter 21. It reflects by the reflective mirror 1, and plane of polarization rotates the laser light of narrow-band CW laser 19 which passed the wavelength plate 23 twice for one fourth 90 degrees, and it goes straight on, a polarization beam splitter 21 is attained and turned up from the laser medium 5 to the reflective mirror 13, and it comes to the reflective mirror 1. Again, if the quarter-wave length plate 23 is passed twice, the light of narrow-band CW laser 19 will return to a generation source. Although it comes out of a resonator after going back and forth between the reflective mirror 1 and the reflective mirrors 13, the light of narrow-band CW laser 19 is always full in a resonator. This CW luminous intensity has enough reinforcement larger than the light which comes out of the laser medium 5 by which it was excited before carrying out a pulse oscillation. From the light which came out of the laser medium 5 since light came to have gone back and forth between the reflective mirror 1 and the reflective mirrors 13 by the effectiveness which was joined to the quarter-wave length plate when the electro-optics component 12 was operated, light passed once after excitation and it was made for plane of polarization to rotate 45 degrees, the light of strong narrow-band CW laser 19 turns into light source, it is amplified by the laser medium 5, and a pulse oscillation is materialized. The wavelength width of face of the oscillation light at this time is the same as that of narrow-band CW laser 19, and peak intensity serves as a sufficiently large pulse laser light compared with narrow-band CW laser 19. If the electro-optics component 12 is operated after pulse amplitude serves as max, the same situation as the gestalt of the 1st operation will happen after this. If oscillation wavelength width of face carries out to

below fixed range of prices peculiar to a sensing element in two-times wave conversion, a match condition will become good and conversion efficiency will increase. Since laser wavelength width of face of the increment in wavelength conversion efficiency and a conversion wave by this effectiveness is narrow-band-ized similarly, it becomes useful when narrow-band-ized light is required in application.

[0036] <the gestalt of the 5th operation> -- as mentioned above, by this invention, loss within a resonator until a laser beam goes and comes back to a resonator and amplifies greatly is made small, reinforcement of a fundamental wave is enlarged, and, so, it has become the features over a conventional method to also make wavelength conversion efficiency increase. For this reason, it becomes an important element which can make loss between resonators small.

[0037] The point using the polarization direction in a polarization beam splitter as S polarization so that the gestalt of this operation shown in drawing 7 can make small the basis of such an idea, and loss by the polarization beam splitter, By moreover, the thing for which the spot location of a beam is constituted so that it may come to the place of the wavelength sensing element 9 while using as the concave surface reflective mirrors 24 and 25 the reflective mirror which constitutes a resonator and making a diffraction loss small by using the reflective mirror 4 as a flat-surface mirror further Insertion of the optical system 8 which adjusts the beam diameter which was being used with the gestalt of operation is excluded.

[0038] Generally, P polarization component with a polarizing element parallel to space is penetrated, and perpendicular S polarization component has the property to reflect. Moreover, compared with the permeability of P polarization component, the reflection factor of S polarization component is larger at this time. So, a laser beam is passed of P component by the polarization beam splitter 11, and when amplifying light, several [about]% of laser beam loses by reflection in this polarization beam splitter 11. On the other hand, in this true form voice, a configuration is changed so that a laser beam may be reflected of S component by the polarization beam splitter 11 and light may be amplified. The general transmission of S polarization component is not fulfilled to 1% in many cases, and so, loss of the light by this polarization beam splitter 11 passage can be made small, and it becomes possible to enlarge magnification of a fundamental wave further.

[0039] Moreover, when a resonator mirror is constituted from a flat-surface mirror, generally, a diffraction loss is large and a diffraction loss becomes [the direction when constituting a resonator from concave surface reflective mirrors 24 and 25 with curvature] small. Although it calls confocal the case where the relation of L=R between

the distance L between resonators and the curvature R of the concave surface reflective mirrors 24 and 25 is in constructing the resonator of bilateral symmetry, a confocal case is a case where this diffraction loss is the smallest and it can do. This true form voice constitutes both the resonators mirror from the concave surface reflective mirrors 24 and 25 with curvature first. At this time, the location of the diameter of a spot where a beam diameter becomes the smallest is generated between resonators. supposing it uses the concave surface reflective mirrors 24 and 25 of the same curvature -- it -- resonator die length -- exactly -- a half location -- it is . If the curvature of R is changed in great numbers, it is also easy to shift the location of this diameter of a spot from a center. In the location used as this diameter of a spot, since the consistency of light increases, there are also an optical element 6 and fear of breakage of 12, but if the wavelength sensing element 9 can be installed near the location of this diameter of a spot, it is possible to raise the consistency of light without contraction of a beam with a lens effectively. Conversely, in order to avoid the damage of a component, as for the acoustooptics component 6 or the electro-optics component 12, it is desirable to separate from the location used as this diameter of a spot as much as possible, and to install in the location where a beam diameter is big.

[0040] A laser beam is passed to the wavelength sensing element 9 by switching of the electro-optics component 12, in the situation which turns up light by the reflective mirror 4 further, the concave surface reflective mirror 25 is installed in the location of the above-mentioned diameter of a spot, and the wavelength sensing element 9 is installed near [as possible] this mirror. Moreover, the reflective mirror 4 consists of flat-surface mirrors. By this, the consistency of light can be raised by placing the wavelength sensing element 9 near the diameter of a spot, and effective wavelength conversion can be performed. Moreover, it is possible to perform wavelength conversion, without the light which returns to the reflective mirror 4 again completely being able to lap with the light which goes and comes back to the reflective mirror 4 from the concave surface reflective mirror 24 according to the effectiveness which turns up light, and breaking down the stability and the function of a resonator by switching of the electro-optics component 12 by putting the reflective mirror 4 on the location of the diameter of a spot. The diameter of a spot comes by combination of the concave surface reflective mirrors 24 and 25 which incidentally consist of the same curvature to L/2 of the locations of the one half of resonator die-length L. At this time, it is necessary to install the reflective mirror 4 in the location of distance L / 2 from the concave surface reflective mirror 25. In addition, by the concave surface reflective mirror 25, since the consistency of light becomes large, it is required to use the mirror with high light-proof

reinforcement which can bear the optical reinforcement enough.

[0041] In addition, in the gestalt of the above-mentioned implementation, although the laser medium 5 used it of an YAG laser, naturally it is not limited to this. If it is the same solid-state component especially as an YAG laser medium at this time, the effectiveness of a maintenance free and handling easy ** will be acquired. Moreover, although there will be no special limit if even the function of wavelength conversion of the wavelength sensing element 9 is obtained, KTP (KTiOPO4) and BBO (BaB 2O4) are suitably applicable, for example.

[0042]

[Effect of the Invention] Invention indicated to [claim 1] as concretely explained with the gestalt of operation above A wavelength sensing element is not put in in the resonance optical axis of the resonator concerned until the reinforcement of the fundamental-wave laser beam which is the pulse laser light in the resonator which a laser medium generates becomes sufficiently large in the laser equipment which has a wavelength sensing element in a resonator. Since it constituted so that a resonator optical axis might be changed and the above-mentioned wavelength sensing element might enter in a resonator optical axis by operating an optical-axis modification means when the above-mentioned reinforcement became sufficiently large When a fundamental-wave laser beam can be amplified in the condition excluding the wavelength sensing element which is lost from on the resonator optical axis and reinforcement becomes sufficiently large for a pulse oscillation, wavelength conversion of a fundamental-wave laser beam can be performed by the wavelength sensing element. Consequently, according to the invention in this application, wavelength conversion efficiency can be raised and the wavelength conversion laser beam of that much big reinforcement can be obtained.

[0043] In the laser equipment which has the wavelength sensing element which indicates invention indicated to [claim 2] to [claim 1], since pulse laser light is obtained by carrying out the Q switch oscillation of the laser beam which a laser medium generates, it can obtain easily the pulse laser light of a fundamental-wave laser beam with big peak value. Consequently, according to the invention in this application, the fundamental-wave laser beam supplied to a wavelength sensing element can be made suitable, and it can ** to the efficient wavelength conversion in a wavelength sensing element.

[0044] In the laser equipment with which invention indicated to [claim 3] has a wavelength sensing element in a resonator The laser medium which is excited by the excitation light source and oscillates a fundamental-wave laser beam, and the reflective

mirror pair which forms the resonator to which is arranged in the both sides of this laser medium, reflects the above-mentioned fundamental-wave laser beam, and a laser medium is made to go and come back, A plane-of-polarization rotation means to rotate the plane of polarization of the light to which it goes and comes back between this reflective mirror pair, A beam splitter mirror with wavelength selection nature which it is installed [nature] on the polarizer which makes the direction of an optical axis of a laser beam which plane of polarization rotated change, and the laser beam shaft with which the direction was changed, and a fundamental wave is reflected [nature], and makes wavelength conversion light penetrate, The wavelength sensing element installed on the optical axis so that the fundamental-wave laser beam which has furthermore passed along the changed optical axis could pass, Since it has a wavelength sensing element in the resonator which consists of a reflective mirror which forms in up to the original optical axis again the resonator installed by return [so that a laser beam may be returned / light] in two waves, a fundamental wave and wavelength conversion light, in order after passing a wavelength sensing element In the condition except a wavelength sensing element, while amplifying a fundamental-wave laser beam, when reinforcement becomes sufficiently large, the plane of polarization of a fundamental-wave laser beam is rotated with a plane-of-polarization rotation means, and further, with an optical-axis modification means, the direction of an optical axis of this fundamental-wave laser beam can be turned to a wavelength sensing element, and can be bent. That is, wavelength conversion is performed based on the pulse of the fundamental-wave laser beam to which reinforcement became large enough. Consequently, according to the invention in this application, wavelength conversion efficiency can be raised and the wavelength conversion laser beam of that much big reinforcement can be obtained.

[0045] In the laser equipment which has the wavelength sensing element indicated to [claim 3], since it established a Q switch oscillation means carried out the Q switch oscillation of the laser beam which a laser medium generates, and obtained the fundamental-wave laser beam which is pulse laser light, invention indicated to [claim 4] starts by actuation of a Q switch oscillation means, and its property is good and it can acquire suitably the pulse of a fundamental-wave laser beam with narrow pulse width with large and peak value.

[0046] In the laser equipment which indicates invention indicated to [claim 5] to [claim 3], since the plane-of-polarization rotation means was constituted from an electro-optics component which rotates the plane of polarization of a fundamental-wave laser beam by impression of an electrical potential difference, only the specified quantity can rotate

the plane of polarization of a fundamental-wave laser beam only by impressing an electrical potential difference. Consequently, according to the invention in this application, incidence of the fundamental-wave laser beam can be suitably carried out towards a wavelength sensing element, and it can ** to the efficient wavelength conversion in a wavelength sensing element.

[0047] Since the polarizer was constituted from a polarization beam splitter in the laser equipment which indicates invention indicated to [claim 6] to [claim 3], the fundamental-wave laser beam which plane of polarization does not rotate can permit magnification by going back and forth between resonators by making it penetrate as it is, and incidence of the fundamental-wave laser beam which plane of polarization rotated can be carried out to a wavelength sensing element by making the optical axis bend and penetrate. Consequently, according to the invention in this application, after the reinforcement of a fundamental-wave laser beam becomes sufficiently large certainly, wavelength conversion of the fundamental-wave laser beam can be carried out, and it can ** to the efficient wavelength conversion in a wavelength sensing element.

[0048] In the laser equipment which has any one wavelength sensing element which indicates invention indicated to [claim 7] to [claim 1] thru/or [claim 6], since the laser medium was formed by solid-states, such as a YAG crystal, it is faced performing wavelength conversion like ****, and a maintenance and handling can use it as easy laser equipment.

[0049] In the laser equipment which has any one wavelength sensing element which indicates invention indicated to [claim 8] to [claim 1] thru/or [claim 6], since the wavelength sensing element was formed as 2 double harmonic generation crystals, such as KTP (KTiOPO4) and BBO (BaB 2O4), it is faced performing wavelength conversion like ****, and a maintenance and handling can use it as easy laser equipment.

[0050] In the laser equipment which has which one wavelength sensing element indicated to [claim 1] thru/or [claim 8], since invention indicated to [claim 9] inserts contraction optical system, such as a lens system and a mirror system, and condenses just before light carries out incidence of the fundamental-wave light of solid state laser to a wavelength sensing element, in order to aim at improvement in conversion efficiency in a wavelength sensing element, it can enlarge peak intensity spatially by this contraction optical system. Consequently, according to this invention, conversion efficiency of a wave can be increase-ized 3 times.

[0051] In the laser equipment which has which one wavelength sensing element which indicates invention indicated to [claim 10] to [claim 1] thru/or [claim 8] The wavelength sensing element for harmonic generations is put into coincidence 3 times as a

wavelength sensing element with the wavelength sensing element for two-times harmonic generations of the wavelength sensing element of [claim 8]. Since it enabled it to take out only two-times higher-harmonic light, 3 time higher-harmonic light, or 3 time higher-harmonic light as an output, the laser beam of such wavelength can be taken out efficiently.

[0052] In the laser equipment which has the wavelength sensing element which indicates invention indicated to [claim 11] to [claim 1] thru/or [claim 8], or [claim 10] Contraction optical system, such as a lens system and a mirror system, is used after the wavelength sensing element for two-times harmonic generations. It condenses to coincidence and fundamental-wave light, two-times higher-harmonic light, or both are put into the wavelength sensing element for harmonic generations 3 times, and since it was made like aiming at improvement in conversion efficiency of a harmonic generation 3 times, the effectiveness of wavelength conversion improves further.

[0053] In the laser equipment which has which one wavelength sensing element which indicates invention indicated to [claim 12] to [claim 1] thru/or [claim 11] Since oscillation core wavelength puts in beforehand almost same another narrow-band continuous-wave-laser light and performs pulse oscillation actuation of a fundamental wave by injection locking in order to narrow-band-ize oscillation wavelength width of face of fundamental-wave light, the light of narrow-band laser turns into light source, it is amplified by the laser medium, and a pulse oscillation is materialized. Consequently, according to this invention, narrow-band-ization of the light of a conversion wave also becomes possible with improvement in wavelength conversion efficiency.

[0054] In the laser equipment which has which one wavelength sensing element indicated to [claim 1] thru/or [claim 12], since invention indicated to [claim 13] makes the polarization direction in laser go as S polarization so that loss of the light which goes and comes back to the inside of a resonator may be performed smallest and makes laser beam loss with a polarizer small, it can enlarge magnification of a fundamental wave further.

[0055] In the laser equipment which has which one wavelength sensing element which indicates invention indicated to [claim 14] to [claim 1] thru/or [claim 13] Since each resonator mirror uses the concave surface mirror with curvature designed so that the diffraction loss of the light in a resonator might be made small while using the mirror of a high reflection factor so that loss of the light which goes and comes back to the inside of a resonator can be performed smallest A diffraction loss can be reduced as much as possible, and amplification degree of a fundamental wave can be enlarged.

[Brief Description of the Drawings]

[Drawing 1] It is the block diagram showing the gestalt of operation of the 1st of this invention.

[Drawing 2] It is the wave form chart showing the timing of each part of the laser equipment of drawing 1 of operation.

[Drawing 3] Average output P2w and pulse width deltatp of the two-times wave laser light in the equipment concerning the gestalt of operation of the 1st of this invention shown in drawing 1 , and the equipment concerning the conventional technique shown in drawing 8 It is the property Fig. showing the comparison result of the numerical-analysis result of an oscillation pulse-repetition-frequency F dependency.

[Drawing 4] It is the block diagram showing the gestalt of operation of the 2nd of this invention.

[Drawing 5] It is the block diagram showing the gestalt of operation of the 3rd of this invention.

[Drawing 6] It is the block diagram showing the gestalt of operation of the 4th of this invention.

[Drawing 7] It is the block diagram showing the gestalt of operation of the 5th of this invention.

[Drawing 8] It is the block diagram showing the laser equipment concerning the conventional technique.

[Description of Notations]

1 Reflective Mirror

3 Reflective Mirror

4 Reflective Mirror

5 Laser Medium

6 Acoustooptics Component

9 Wavelength Sensing Element

10 Excitation Light Source

11 Polarization Beam Splitter

12 Electro-optics Component

13 Reflective Mirror

14 Two-Times Wave Sensing Element

15 3 Time Wave Sensing Element

16 Reflective Mirror

18 Contraction Optical System

19 Narrow-band CW Laser

20 Reflective Mirror

21 Polarization Beam Splitter

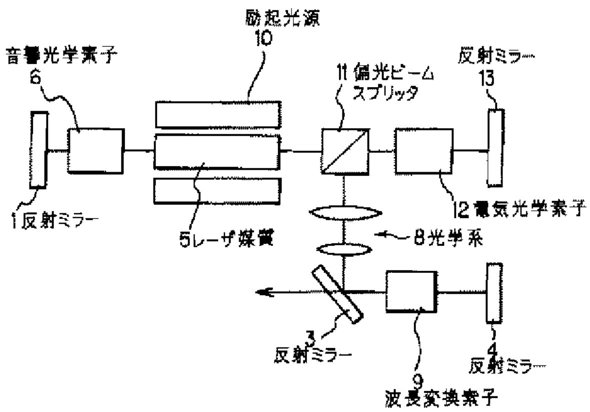
22 Electro-optics Component

23 1 / 4 Lambda-Wave Length Plate

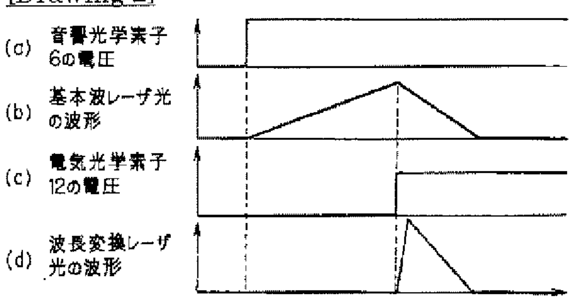
24 Concave Surface Reflective Mirror

25 Concave Surface Reflective Mirror

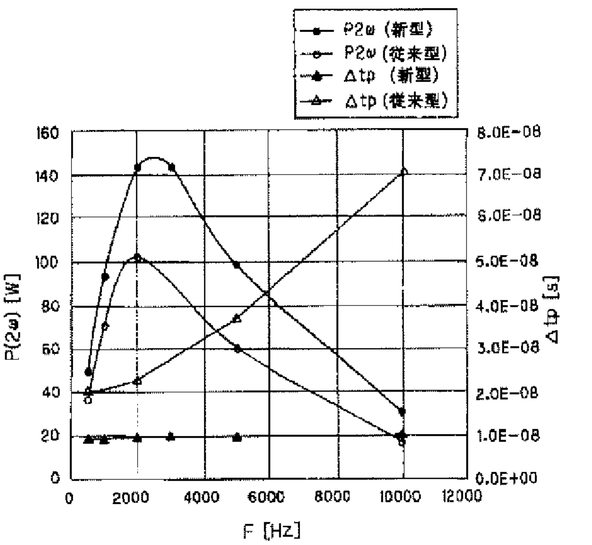
[Drawing 1]



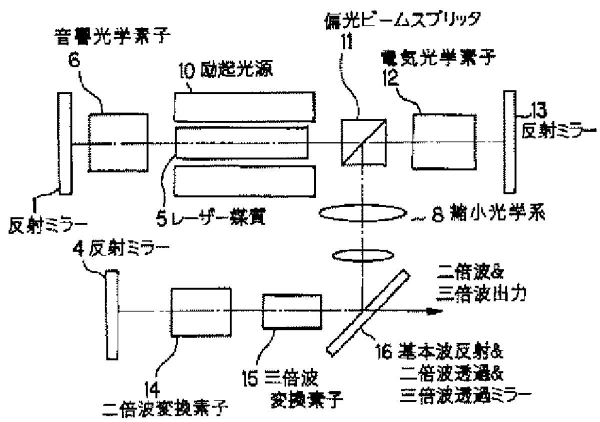
[Drawing 2]



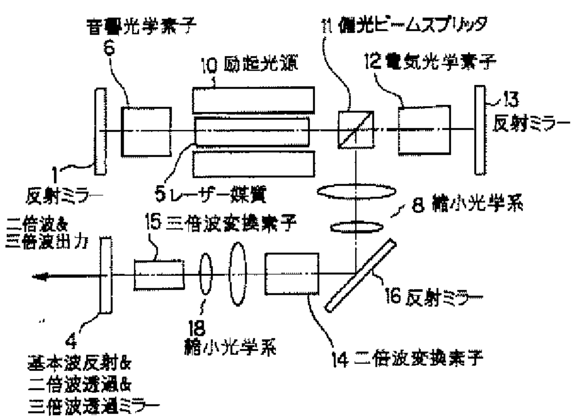
[Drawing 3]



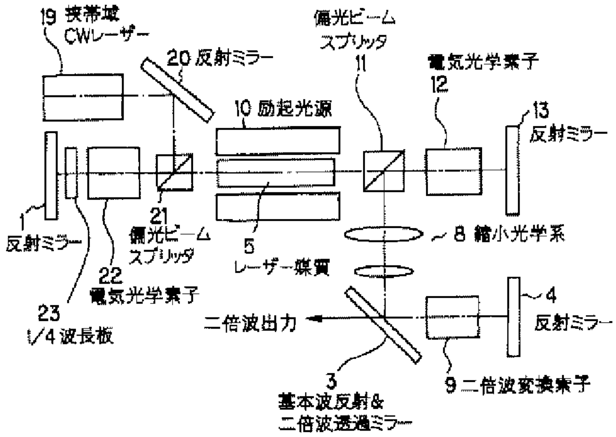
[Drawing 4]



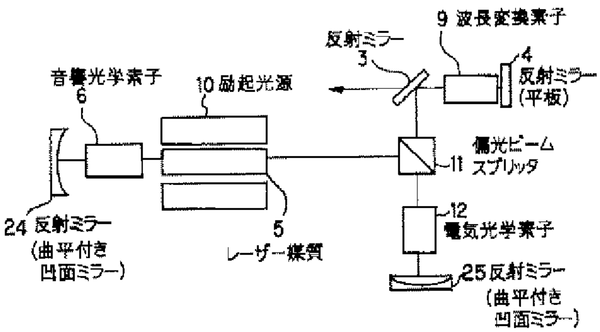
[Drawing 5]



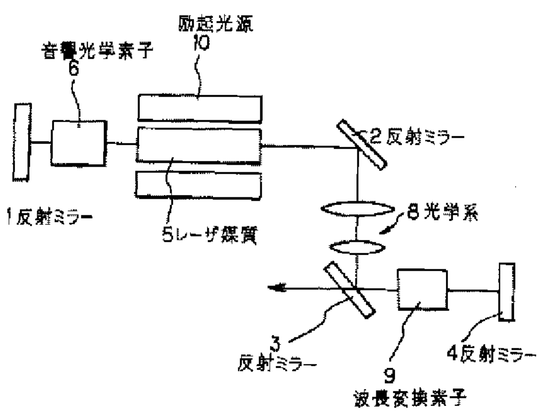
[Drawing 6]



[Drawing 7]



[Drawing 8]



* NOTICES *